

# Milling Machines

A milling machine is a power driven machine that cuts by means of a multitooth rotating cutter. The mill is constructed in such a manner that the fixed workpiece is fed into the rotating cutter. Varieties of cutters and holding devices allow a wide range of cutting possibilities.

The mills in the Student Shop are vertical milling machines, commonly called “Bridgeport” style mills. These versatile mills are capable of performing many operations, including some that are similar to those performed on the drill press like drilling, reaming, countersinking, and counterboring. Other operations performed on the mill include but are not limited to: side and face milling, flycutting, and precision boring.

Mills are classified on the basis of the position of their spindle. The spindle operates in either a vertical or horizontal position. The amount of horsepower the mill is able to supply to the cutter is also often important.

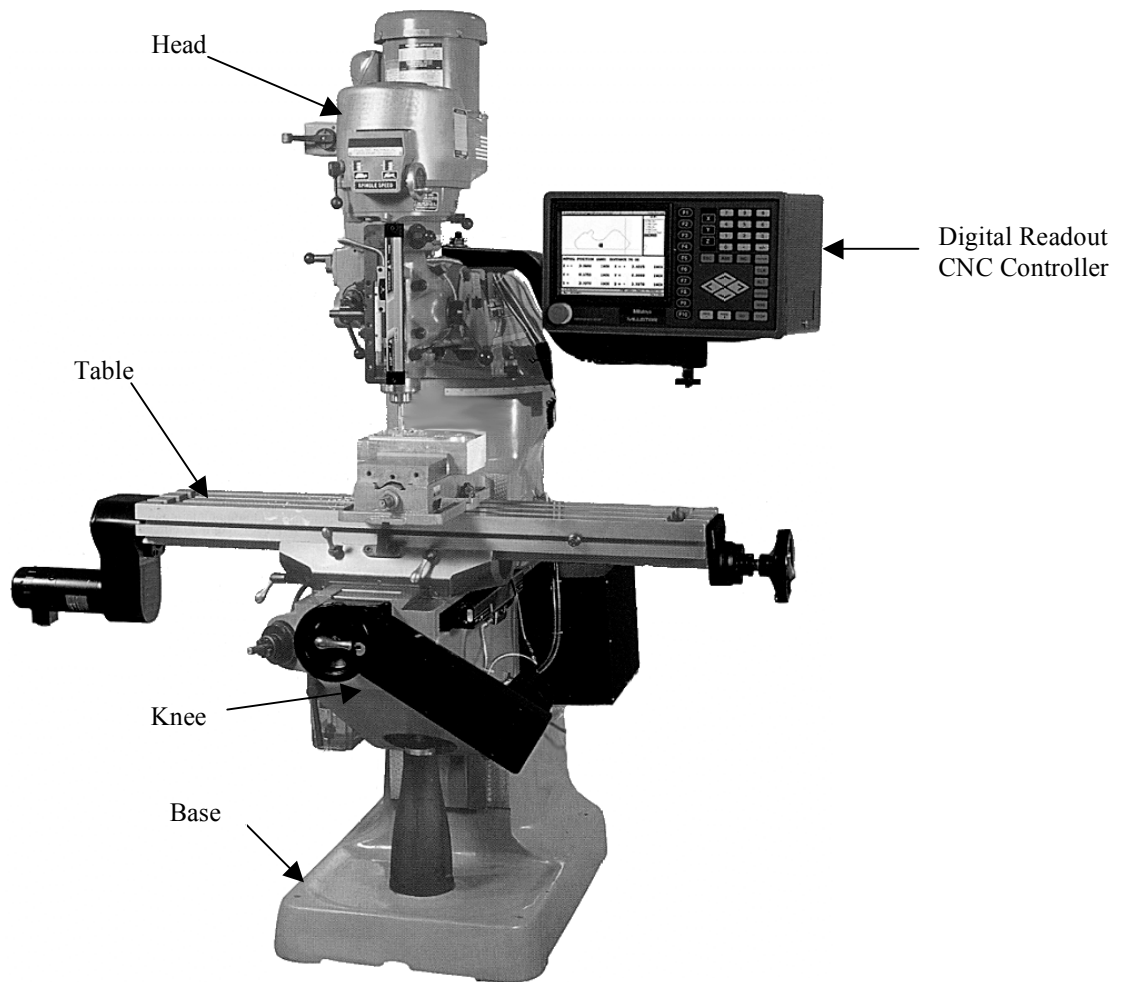
## ***Mill Construction;***

The vertical milling machine is made up of five major groups: base and column, knee, saddle, table, and head, (see figure). The base and column are one piece that forms the major structural component of the milling machine. They are cast integrally, and provide the mill with its stability and rigidity. The front of the column has a machined face which provides the ways for the vertical movement of the knee. The knee supports the saddle and table. It contains the controls for raising and lowering the saddle. Sitting atop the knee is the saddle which supports the table. The saddle slides in dovetailed grooves into and away from the machine, providing the mill with its Y-axis movement. On top of the saddle sits the table. Being moved side-to-side, left-right, over the saddle furnishes the mill with its X-axis movement. The workpiece is secured to the table through the use of various types of holding devices.

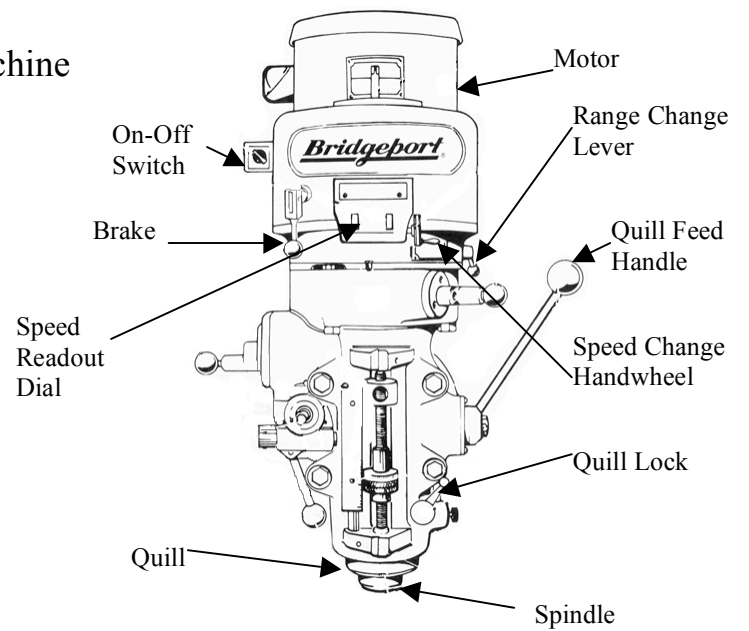
The head is the most complex assembly in the major parts groups. This contains the following components:

1. The drive motor and on/off switch.
2. Drive belt, gear train, and range lever selector.
3. Quill, spindle, and draw bar.
4. Quill feed, lock, and digital depth read out (Z-axis).

\*\*\* The on/off switch is an electrical switch, with positions marked high and low. This is nothing more than an electrical reversing drum switch. Its position selection is done to match that of the range lever selector. Changing the range from high to low or vice-versa is done through the use of the range lever selector and not the on/off drum switch. ***This is a static adjustment, and done with the motor turned OFF!*** Check to be sure the gears are fully engaged before turning on the motor. Do this by manually rotating the spindle. Spindle speeds are adjusted with the hand wheel on the right front part of the head. ***This is a dynamic adjustment, and done with the motor ON!***



Vertical Milling Machine



Vertical Milling Machine-Head

The spindle is located within and moved up or down by the quill. This is the Z-axis movement for plunge operations on the vertical mill. The quill is moved by the quill feed lever, and can be locked in place with the quill lock. Depth of plunge moves are measured with the electronic digital read out located on the front of the mill head.

## ***Procedures;***

Proficiency in milling operations involves more than simply cutting metal. There are two main categories of procedures when machining on a milling machine: the preliminary operations, and the machining operations.

### ***Preliminary Operations-***

*Cleaning-* The first, (and last), procedure in any machining operation. Without clean equipment and tools, the accuracy of the finished product diminishes quickly. The accuracy, durability, and longevity of the equipment and tools depend on being kept clean. In today's high tolerances in engineering, cleanliness is critical.

*Set-up-* For most jobs performed on a milling machine, setting up the workpiece is the most difficult, critical, and time consuming part of the job. The workpiece must not only be securely clamped, but held in such a way so that every surface to be machined will accurately align with other surfaces when finished. Several types of holding devices are used in mounting the workpiece on the milling machine. The most common used in the Student Shop are the vice, table clamps, index chuck, and rotary table. The vice is probably the most widely used fixture. There are two configurations for the vise. The plain vise, which rests with the jaws parallel to the X-axis. The second style is with the swivel-base mounted under the vise allowing it to be rotated and set at a variety of angles. Large workpieces can be held directly on the table surface through a combination of T-nuts, bolts, and clamps. An index chuck permits the rapid positioning of the work, usually indexing in 15° increments. The rotary table gives the mill its 4th axis with its circular movement. Circles, partial curves, angularly spaced holes, curved slots, and O-ring grooves. This fixture is graduated in degrees and minutes of a degree.

*Tooling-* End mills are the most common cutter used on the vertical milling machine. They are extremely versatile in that they can be used for surface cuts, slotting, and side (or profiling) cuts. End mills come in many types, each being suited for a particular application. End mills are fluted, much like drills, and the number of flutes determines what the end mill can do. Two fluted end mills are used for machining aluminum, and are favored for plunge cuts. Four fluted end mills are used in machining the harder metals like steel. Generally, it is not a good idea to use a four fluted end mill when machining aluminum or brass however, since the flutes can fill with material, and no longer cut. The other main characteristic of the end mill is the cutting end of the tool is its self. Some end mills are bottom cutting, meaning they can be plunged into material much like a drill, while some are not, and are only useful for cutting on the side. Be careful not to plunge an end mill that is not bottom cutting. Other types of end mills includes the ball end mill, which has a radius end used to produce a fillet, and corner radius end mills, used to round the edges of a workpiece.

Other types of cutters include slitting saws for cutting grooves, shell milling cutters for faster milling of surfaces than is possible with an end mill, flycutters (which are single point cutters for facing large workpieces), formed cutters for cutting special shapes like gears; and groove cutters like T-slot and dovetail cutters.

Milling cutters are expensive and easily ruined if not taken care of when using or storing. Failure to obtain satisfactory results on a job can many times be attributed to inappropriate selection of the proper milling cutter.

*Machine Controls-* The speed or RPM of the spindle is set through a variable-speed changing mechanism. This is a *dynamic* adjustment. Speed changes are done only with the motor running. This is different than the range changes, which are done only with the motor turned off, *static*. The feed is the rate that the workpiece is fed into the cutter. The shop mills are equipped with a variable power feed. This means that while it is easy to feed at a very slow feed, it is also easy to accidentally feed too fast when using a small cutter, possibly breaking the cutter while in operation. Many factors and conditions influence the speed and feed at which the material is worked. The operator must take into account rigidity of the workpiece and cutter, the depth of cut, and the desired finish. It is generally a good idea to start with a slow feed rate, and increase it until an efficient removal rate is achieved. Feed rates are decreased for finer finishes or greater depths of cut, and maximized for roughing cuts.

### ***Machining Operations;***

Once the preliminary operations and selections have been accomplished, a quick check should be made to be sure that work and fixtures will clear any parts of the machine, and that the cutter will not strike the table or fixtures. All table movements that will not be used on a cut should be locked, and those that will be used should be unlocked. The head controls should be checked for proper range and speed. When starting the motor, make certain the cutter is rotating in the proper direction. Do not stop the cutter in mid cut and make no adjustments with the cutter in contact with the workpiece.

There are two types of milling to be discussed. Conventional milling is where the workpiece is fed opposite the direction of the rotation of the cutter, and climb milling is when the workpiece is fed in the direction of rotation of the cutter. Each has its own advantages and disadvantages. Climb milling draws the part into the cutter, and can violently take up any backlash in the table. However, it does produce a smoother finish. Conventional milling is the more preferred method, and will be used for every cut except the finishing cut.

When using an end mill, there are certain general rules that should be followed when making cuts.

1. The greatest depth of cut should never be more than 1/2 the diameter of the end mill.
2. Do not plunge an end mill more than 1-1/2 times its diameter. This is also true for slotting. Do not, in a single pass, cut a slot deeper than 1-1/2 its width.
3. Do not edge mill to a depth of more than 1-1/2 times the diameter of the cutter.

## ***Safety;***

The vertical mill can be a safe machine, but only if the student is aware of the hazards involved. In the machine shop you must always keep your mind on your work in order to avoid accidents. Distractions should be taken care of before machining is begun. Develop safe working habits in the use of safety glasses, set-ups, and tools. The following rules must be observed when working on the milling machines in the Student Shop:

1. No attempt should be made to operate the mill until you understand the proper procedures for its use and have been checked out on it.
2. Dress appropriately. Remove all watches and jewelry. *Safety glasses or goggles are a must.*
3. Plan out your work thoroughly before starting.
4. Know where the location of the OFF switch is.
5. Be sure the work and holding device are firmly attached to the table.
6. Get help in moving any heavy attachments associated with the mill.
7. Stop the machine before making any adjustments or measurements.
8. Never reach over or near any rotating cutter.
9. Take care to prevent running the cutter into the vice or table.
10. Never leave a machine running unattended.
11. Stop the machine before removing chips, ( remember that chips can be very sharp).
12. Keep the floor around the machine clear of chips. Wipe up spilled cutting fluids immediately.
13. Use a piece of cloth for protection of the cutter and your hands when handling the milling cutters.